CLAIMS

1. In an optical communication system, apparatus for amplifying an optical signal, said apparatus comprising:

a fiber; and

an optical pump energy source disposed to inject optical pump energy into said fiber in a co-propagating direction relative to a transmission direction of an optical signal in said fiber to cause Raman amplification of said signal in accordance with a gain level; and

wherein said gain level is greater than 4 dB.

2. The apparatus of claim 1 wherein either 1) given a signal-to-noise ratio, there is a greater four-wave mixing product suppression level than would be achieved using only a counter-propagating optical pump energy source to obtain said gain level or 2) given a four-wave mixing product suppression level, there is a higher signal to noise ratio than would be achieved using only said counter-propagating energy source to obtain said gain level.

3. In an optical communication system, apparatus for amplifying an optical signal, said apparatus comprising:

a first optical pump energy source disposed to inject optical pump energy into a fiber in a co-propagating direction relative to a transmission direction of said optical signal to cause Raman amplification of said signal in accordance with a first gain level;

a second optical pump energy source disposed to inject optical pump energy into said fiber in a counter-propagating direction relative to said transmission direction of said optical signal to cause Raman amplification of said signal in accordance with a second gain level, said optical signal experiencing a total gain level including said first gain level and said second gain level; and

wherein said first gain level is greater than 4 dB.

4. The apparatus of claim 3 wherein either 1) given a signal to noise ratio, there is a greater four-wave mixing product suppression level than would be achieved using only said second optical pump energy source to obtain said total gain level or 2) given a four-wave mixing product suppression level, there is a higher signal to noise ratio than would be achieved using only said second optical pump energy source to obtain said total gain level.

5. The apparatus of claim 3 wherein said first gain level is set responsive to a minimum tolerable four-wave mixing product suppression level and a desired signal to noise ratio.

6. The apparatus of claim 5 wherein said first gain level is also set responsive to a maximum tolerable saturation level.

7. The apparatus of claim 5 wherein said second gain level is set responsive to said first gain level and said total gain level.

8. ~~The apparatus of claim 3 wherein said first gain level and said second gain level are set responsive to a desired maximum double Rayleigh backscattering level.~~

9. ~~The apparatus of claim 3 wherein a power level of said first optical pump energy~~ source is set responsive to said first gain level.

10. The apparatus of claim 3 wherein a power level of said second optical pump energy source is set responsive to said second gain level.

11. The apparatus of claim 3 further comprising said fiber.

12. The apparatus of claim 3 further comprising:

~~an Erbium-doped fiber amplifier in cascade with said fiber.~~

~~13. In an optical communication system, apparatus for amplifying an optical signal,~~ said apparatus comprising:

a first optical pump energy source disposed to inject optical pump energy into a fiber in a co-propagating direction relative to a transmission direction of said optical signal to cause Raman amplification of said signal; and

a second optical pump energy source disposed to inject optical pump energy into said fiber in a counter-propagating direction relative to said transmission direction of said optical signal to cause Raman amplification of said signal; and

wherein said first gain level is greater than 4 dB.

14. The apparatus of claim 13 wherein either said first optical pump energy source has a power level set to achieve one of a desired gain saturation level or a desired Rayleigh backscattering level, and said second optical pump energy source has a power level set to obtain a desired gain level given said power level set for said first optical pump energy source.

15. The apparatus of claim 13 wherein either 1) given a signal to noise ratio at an output of said fiber, there is a greater four-wave mixing product suppression level achieved than would be achieved using only said second optical pump energy source to achieve said desired gain level or 2) given a four-wave mixing product level at an output of said fiber, there is a higher signal to noise ratio than would be achieved using only said second optical pump energy source to achieve said desired gain level.

16. The apparatus of claim 13 further comprising said fiber.

17. The apparatus of claim 16 further comprising an Erbium-doped fiber amplifier in cascade with said fiber.

18. In an optical communication system, a method for amplifying an optical signal within a fiber by exploiting Raman effects to achieve a desired gain level, said method comprising:

injecting co-propagating optical pump energy into said fiber to cause Raman amplification according to a first gain level;

injecting counter-propagating optical pump energy into said fiber to cause Raman amplification according to a second gain level; and

wherein said first gain level is greater than 4 dB.

19. The method of claim 18 wherein either 1) given a signal to noise ratio at an output of said fiber, there is a greater four-wave mixing product suppression level than would be achieved injecting only said counter-propagating optical pump energy to obtain said desired gain level or 2) given a four-wave mixing product level, there is a higher signal to noise ratio than would be achieved using injecting only said counter-propagating optical energy to obtain said desired gain level.

20. The method of claim 18 wherein injecting co-propagating optical pump energy comprises injecting co-propagating optical energy at a power level set responsive to a minimum tolerable four-wave mixing product suppression level and a desired signal to noise ratio.

21. The method of claim 20 wherein said power level is also set responsive to a maximum tolerable saturation level.

22. The method of claim 20 further comprising:

further amplifying said signal within an Erbium-doped fiber amplifier.

23. In an optical communication system, apparatus for amplifying an optical signal within a fiber by exploiting Raman effects to achieve a desired gain level, said method comprising:

means for injecting co-propagating optical pump energy into said fiber to cause Raman amplification;

means for injecting counter-propagating optical pump energy into said fiber to cause Raman amplification according to a second gain level; and

wherein said first gain level is greater than 4 dB.

24. The apparatus of claim 23 wherein either 1) given a signal to noise ratio at an output of said fiber, there is a greater four-wave mixing product suppression level than would be achieved injecting only said counter-propagating optical pump energy to obtain said desired gain level or 2) given a four-wave mixing product level, there is a higher signal to noise ratio than would be achieved injecting only counter-propagating optical energy to obtain said desired gain level.

25. The apparatus of claim 23 wherein said means for injecting co-propagating optical pump energy comprises means for injecting co-propagating optical energy at a

power level set responsive to a minimum tolerable four-wave-mixing product suppression level and a desired signal to noise ratio.

26. The apparatus of claim 23 wherein said power level is also set responsive to a maximum tolerable saturation level.

27. The apparatus of claim 23 further comprising:

means for further amplifying said signal within an Erbium-doped fiber amplifier.